August 24th, at night.—Slight shock; sultry, with rain.

August 27th, 2 a.m.—Slight shock, rained heavily. 9.10 p.m.—Slight shock, oscillating, lasted several seconds; sultry and overcast.

September 14th, 5 p.m.—Sharp shock.

October 16th, 6.30 a.m.—Slight shock; day fine and calm.

October 17th, 3 a.m.—Two severe shocks, and one slight one.

Art. XII.—*On the Probability that a Connexion of Causation will be shown to exist between the Attraction of Gravitation and the Molecular Energy of Matter.*

By Alexander Sutherland, M.A.

[Read on the 13th Sept., 1877.]

In his recent paper on "Force" Mr. Pirani asks what is meant when we say that one portion of matter attracts another. Is it to be supposed that just as a conscious being exerts a force upon an external object, so does one inanimate body exert a force upon another? To this notion he takes exception, and, as I conceive, with justice. For the idea that that which is itself devoid of energy should have the power of imparting energy to another body is opposed to all our intuitive beliefs.

Yet the fact remains, that when two bodies are placed in space at a distance from each other, and left to themselves, each begins to set the other in motion—that is, each imparts to the other a certain amount of kinetic energy.

Here we have a difficulty: on the one hand it is inconceivable that inanimate bodies should have the power of doing work, on the other there is every reason to believe that two portions of matter can do work upon one another. But in this connexion is not the word inanimate altogether misapplied? Now that we know all matter to be replete with energy, would it not be more correct to regard it as in certain respects animate? Seeing that it is possessed of energy, it must be possessed of the power of doing work, and if we could establish a connection between this internal molecular energy of matter and its power of doing

work upon other matter, we should at once remove this inconsistency.

Our proposition would then be that two portions of matter animated by vast internal energies which are similar in all respects to the energies of animals, except that they are not accompanied by consciousness, have by virtue of this internal energy the power of doing work.

I desire in this paper to inquire how far we should be justified in thus seeking in the known molecular energy of matter the attractive power which this matter certainly possesses.

If there be two bodies at a certain distance from one another, each is found after a certain time to be possessed of kinetic energy, which was not previously in existence; and we have to inquire from what source this energy has been derived.

In accordance with the principle of the conservation of energy, the reply must be that it has sprung from some antecedent energy; for if the sum total of energy in the universe be constant then energy cannot be created, and cannot be produced from something which is not energy.

Now let us ask—What is the pre-existent energy from which the energy of these attracting bodies has been derived?

We must carefully avoid being misled by the use of such a term as "Potential Energy;" for in referring the energy whose origin we seek to what is called potential energy, we should at once beg the whole question. When Professor Rankine invented this term, he never intended that it should be used to represent any real form of energy. It is an analytical artifice of great use, but merely representing the potentiality as distinguished from the actual existence of energy. It is a condensed statement of the fact that if a body be left to itself it will after a certain time have acquired a certain amount of energy. But the question we propose is still untouched—From what source has this derived energy been obtained?

We have to decide in what direction we may, with most hope of success, seek this unknown source. Is it external to the attracting bodies, or is it internal? In other words, when two portions of matter in space begin to move towards one another, is this motion due to external energies *driving* them together, or to the internal energies of matter itself tending to *draw* the two portions together?

There can be little doubt that the latter is by far the more promising direction of inquiry. For we know that all matter is possessed of eternal energy, whose amount is far more than sufficient to explain all the known effects of gravitation. Each atom is for ever in motion, and therefore fraught with its own store of kinetic energy due to this motion, the gross amount of these molecular energies being far beyond any force to which living beings can pretend.

On the other hand, to refer the energy arising from gravitation to energies external to the bodies themselves, is in every way unsatisfactory. Newton at first declined to speculate on this subject, declaring that there was no known energy external to the bodies to which their resulting energy could be attributed. Pressed by the importunities of his friends, he formed a theory of the causation of gravitation, referring it to supposed external agencies; but he attaches no value to his speculations, as they are based on the utterly unscientific method of explaining the existence of a known effect, by assuming the existence of an imaginary cause invented for the sole purpose of explaining that effect.

The same objection is open to the theories of Lesage and Mossotti. *If* we allow to Lesage that the universe is filled with extra-mundane particles, moving at high velocities and impinging on all bodies, and *if* we allow that these bodies have a cage-like structure, then gravitation may be partly explained; but an hypothesis which calmly assumes two important propositions, for the purpose of partially explaining a third, introduces more difficulties than it removes.

In the same way Mossotti requires us to allow, first, that all particles of matter repel one another, which is a gratuitous assumption; secondly, that all particles of intervening ether repel one another, which is a second gratuitous assumption; thirdly, that particles of ether and particles of matter attract one another, a third assumption, with this special objection, that it assumes the whole question, when it speaks of attraction between particles. Here, then, we have three assumptions for the purpose of explaining a single fact. The mathematical part of the work is handled in a masterly way; but just as an equation is not solved, if we introduce unknown quantities and allow them to remain in our final

result, so if we introduce assumed facts in explaining a known fact, there is in effect no explanation given.

But the internal energy of matter due to the motion of its molecules, is at present a well-established fact, and is free from the objection of being an hypothetical existence assumed for the purpose of explaining a known fact.

The case then may be stated thus: When two bodies are placed near one another and left to themselves, each acquires a certain energy. This must have been derived from some antecedent energy; but the only antecedent energy known to exist is that due to molecular motion. Hence we shall be justified in turning our investigations, whether experimental or mathematical, in that direction.

This is an explanation which has not been possible until within late years. Newton never dreamt that what we call inanimate matter is in reality animated by vast energies; had he known this fact he would perhaps not have regarded it as an absurdity that two such bodies should exert forces upon one another.

That gravitation is due to molecular energy is also the result of the following consideration drawn from the analogy between gravitation and the forces of magnetism and electricity. These three forces are the only known forms of attraction at sensible distances. They differ among themselves in many respects, but they are, in their main features, so similar as to form a class very distinctly marked off from all other existences. Now it is certain that magnetism and electricity are caused in some unknown manner by the energy of material molecules. But when the forms of energy are absent to which these two kinds of attraction are peculiarly due, the portions of matter in question are still endued with the other forms of molecular motion, and are still found to possess a power of attraction similar to, though much less intense than, the other attractions. Is there not a large measure of probability in the belief that also in the case of this universal form of attraction, the force is due to the universal form of molecular energy?

A more definite idea of what is meant will perhaps be obtained in this way:—When an electro-magnet attracts a piece of iron in front of it the following action goes on:—Molecular vibrations are originated in the battery and pass into the core of the magnet. From this core they are propagated out into space in the form of waves, and, in some

undetermined way, the molecular energy of these waves is converted into the kinetic energy of the piece of iron. So in the case of a permanent steel magnet, it has been shown by Clerk-Maxwell, Verdet, De La Rive, and Wertheim, that the attractive force is due to the molecular state both of the attracting and the attracted body.

Now, take the case of a steel magnet which has been heated and allowed to cool. It has lost its special molecular energy, and its special attractive force; but it now possesses the ordinary form of energy common to all matter, and likewise possesses the ordinary form of attraction common to all matter. Since, then, in its former state, its attractive power is known to be due to the energy of its atoms, there is a strong presumption, in the absence of any other explanation, that the attraction and the molecular state in the second condition, are causally connected.

The following, therefore, is the theory to which the facts point:—When two bodies are placed near one another, the internal energy with which each is actuated is radiated into space, but such of it as is intercepted by the other is converted into kinetic energy in a manner analogous to that in which the molecular vibrations of an electro-magnet radiate and produce kinetic energy in the attracted iron.

If this theory could be shown to be true, it would explain certain facts which seem otherwise to be inexplicable.

For instance, suppose a mass of iron at the surface of the earth to weigh one ton; then, if it were to be carried fifteen hundred miles upwards from the surface, it would weigh only half a ton. Now, what would become of the lost weight? Faraday spent some months in trying to discover if weight lost in this manner is turned into electricity; but his experiments gave no hopeful result. No other explanation has been given of this apparent disappearance of something from existence. But it is possible, that though this particular mass of iron has lost something, yet that something has, nevertheless, not been lost from existence. And this is the result our proposition would give. For if we imagine a body in a certain position to receive a certain amount of the molecular waves proceeding from another body, then, when removed to twice the distance, it would receive only one-fourth the amount it previously received. The remaining three-fourths would be lost to this particular body, but would not be lost from existence—it would travel out into space;

and though it became attenuated the further it spread, yet it would as truly conform to the law of the conservation of energy as light does when not intercepted, but allowed to radiate into space. Thus, though our ton of iron loses half its weight, the loss could be easily accounted for without supposing the annihilation of anything.

Again, it is known that all space is filled by a medium which is capable of conveying molecular vibrations; that it conveys the motions of heat and light is certain; that it likewise conveys the motions which constitute magnetism and electricity was the belief of Faraday, and is now held by Thomson, Tait, Maxwell, and others who have written on the subject.

Now Newton demands a medium for the conveyance of the effects of gravitation. In his letter to Bentley, he says—"That one body may act upon another at a distance, through a vacuum, without the medium of anything else by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can fall into it."

This assertion has been severely criticised. Still the reasoning on which Newton bases it is sound, and it is now generally held to be justifiable.

Now since the ether which is known to fill space has the power of conveying molecular vibrations, this fact tallies very well with the supposition that gravitation is itself due to waves of molecular vibration.

Our supposed origin of gravitation satisfies sufficiently well the necessary condition of supplying an explanation of the known laws to which gravitation is subject.

First, the attraction which a body exerts is proportional to the amount of matter it contains. This is consistent with our supposition. For it has of late years been conclusively shown that matter is simply a name for a collection of such energies as are capable of making an impression on the senses. Thus the qualities of a body are dependent on the amount it contains of the various forms of molecular energy; and its mass must depend upon the amount it possesses of some constant form of energy. Hence if we suppose that gravitation is proportional to this form of energy, it necessarily follows that gravitation is proportional to the amount of matter in the body.

The second law has a greater significance than this. The attraction of one body on another varies inversely as the square of the distance between them. If r be the distance between the two bodies, then one of the factors of the expression for their attraction is r^2. Now r is a surface quantity, and if gravitation were a simple force acting in a simple straight line from a particle of one body to a particle of the other, then it would be difficult to conceive of any explanation for the entrance of such a factor.

But in the case of magnetic attraction, or of any other form of radiation, we can see easily enough the origin of this term. For in all cases of waves propagated from a centre, the square of the distance naturally enters. As the wave moves forward, it expands equally in two directions, and the expansion in each direction being proportional to the distance traversed, the intensity of the wave is lessened in proportion to the square of the distance traversed. Hence the inverse square is the law for light, heat, magnetism, and electricity. If we find the same law in the case likewise of gravitation, it strengthens to a certain extent the supposition that the internal energy of matter is radiated through space in spherical waves which obey the ordinary law of such waves, and decrease in intensity in proportion to the squares of distances they have travelled.

In conclusion, it may be observed that of all the possible explanations that could be given of gravitation, the simplest and most likely is that the power of attracting lies in the mass of matter itself; and if we ask what it is in matter that gives it this power, we can scarcely have any other answer than that it is some form of energy due to the motion of the constituent molecules. It certainly would be a step in the establishment of that conformity of nature, to which all science tends, if it could be shown for gravitation, as it has recently been shown for electricity and magnetism—that it is the effect of molecular vibrations propagated through the same omnipresent medium which conveys the vibrations of light, heat, and actinism. Of course, no real advance will be made in such a theory until, by fresh experiments, or by mathematical investigations, founded on previous experiments, something like a reasonable explanation shall be given for the nature of the connection that binds the two together; till we shall be able to say how it is that a molecular dis-

turbance propagated from one body is converted into an attractive force upon the other. And yet the present theories of electricity and magnetism are in the same state. It is simply known that they are the result of molecular waves, but the nature of the transformation is as yet a mystery. Clerk-Maxwell has given in six papers in the *Philosophical Magazine* for 1861-1862 a provisional theory for magnetism; but there has been no great advance made in this direction. That the full connection will ere long be discovered, is almost certain; and in the meantime it will not be without its purpose to point out that in the course of time it will, in all probability, be necessary to extend the same investigation to gravitation.

Art. XIII.—*Experiments on the Comparative Power of some Disinfectants.*

By James Jamieson, M.D.

[Read on the 11th October, 1877.]

The object of the present communication is to record the results of a series of experiments on the comparative power of certain disinfectants when applied in the form of vapour. While this department of the subject has undoubtedly great practical importance in many ways, it has been comparatively little cultivated, due no doubt, in some measure at least, to the difficulty which attends any attempt to carry out such investigations in an exact way. It so happens, therefore, that our knowledge on the subject of aërial disinfection is made up mainly of vague impressions, which may perhaps be tolerably correct, but which are greatly in need of a basis of well-established facts and scientific investigations.

It would be out of place for me to enter at any length on the general question of the nature of those remarkable processes included under the terms putrefaction and fermentation; but it is necessary to state the opinion I hold on the subject, which is that now generally accepted by men of science. It may be said, then, that putrefaction, fermenta-